AD-A187 264 DATA ACQUISITION AND PROCESSING FOR SURFACE PLATE CALIBRATION(U) ADVANCED ENGINEERING LAB ADELAIDE (AUSTRALIA) R W LEVINGE MAR 87 AEL-0286-TM 1/1

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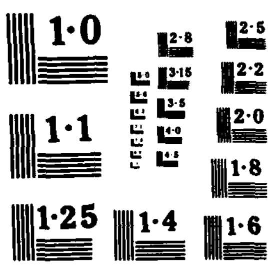
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AUSTRALIA

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DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

ADVANCED ENGINEERING LABORATORY

DEFENCE RESEARCH CENTRE SALISBURY
SOUTH AUSTRALIA

## TECHNICAL MEMORANDUM

AEL-0286-TM

## DATA ACQUISITION AND PROCESSING FOR SURFACE PLATE CALIBRATION

R.W. LEVINGE

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# DATA ACQUISITION AND PROCESSING FOR SURFACE PLATE CALIBRATION

R.W. Levinge


## S U M M A R Y

A method for acquiring and processing data for surface plate calibration is described. It controls acquisition procedure, minimises the work of analysis and presents the results as departures from a mean plane at a number of fixed points on the surface. Automatic entry and storage avoids copying errors when reading data.


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# 1. INTRODUCTION

The plate is held in a nominal horizontal x-y plane and z-axis departures are computed from gradients measured at intervals over the surface. Measurements, accurate to 0.2 s of arc, are made in sequence along equally spaced grid lines, or generators, parallel to x and y axes. Calibration points are at line intersections, the number of which depends on the pattern selected. Accuracy is improved by repeating, several times, the measurement at each interval. Figures 5 to 11 illustrate those grid patterns which may be selected.

The Talyvel, pendulum operated, measures gradient referred to vertical. It is small, light generating little heat but requires the plate to be undisturbed during the calibration. A modified Talyvel with digital output has a range of 250 0.2 s of arc increments. Data, entered by push button, are stored for later processing into departures from a mean plane. The Talyvel is cabled to its display unit and thence to the Data Unit, both on a separate stand.

Manual data processing derived profiles for each generator from measured gradients. Profiles were then assembled into a closed three dimensional shape. The largest likely pattern, with 32 generators, demanded considerable work and those with four diagonal generators could not be assembled with any reasonable accuracy. This method of data acquisition and processing reduces workload, reduces errors, compares repeat readings, controls the measurement sequence and presents the results in a desired report format. Available graphics programs give magnified three dimensional viewing of the calibrated surface.

The equipment, shown in figure 1, consists of a Data Unit to indicate measurement intervals, to display digitised gradients and to receive and store data. Pattern size and number of repeats are selected on the Unit before calibration starts. Data, stored in a non-volatile memory, are transmitted over RS 232 lines to an IBM Personal Computer (PC) which is a terminal to an IBM 370 computer. Several sets of data, relating to a number of surface plates, are bulk transmitted to the PC and separately identified by the PC operator. At the same time reference data are added to each set. The Unit memory is now empty and can accept new data. The operator sends each set in turn to the IBM 370 and receives back the processed data which are then printed out. The PC requires an IRMACARD for data transmission to the IBM 370 and a graphics printer for the formatted report.

One alternative way of measuring gradient uses two parallel laser beams to sense tilt of a double corner reflector. The relative phase shift of the two beams is an accurate measure of tilt angle. By transmitting the beams through an interferometer mounted on the edge of the plate, errors due to plate disturbance are avoided. Very careful alignment is necessary to obtain a measure but it is adaptable to the proposed method of acquisition and processing.

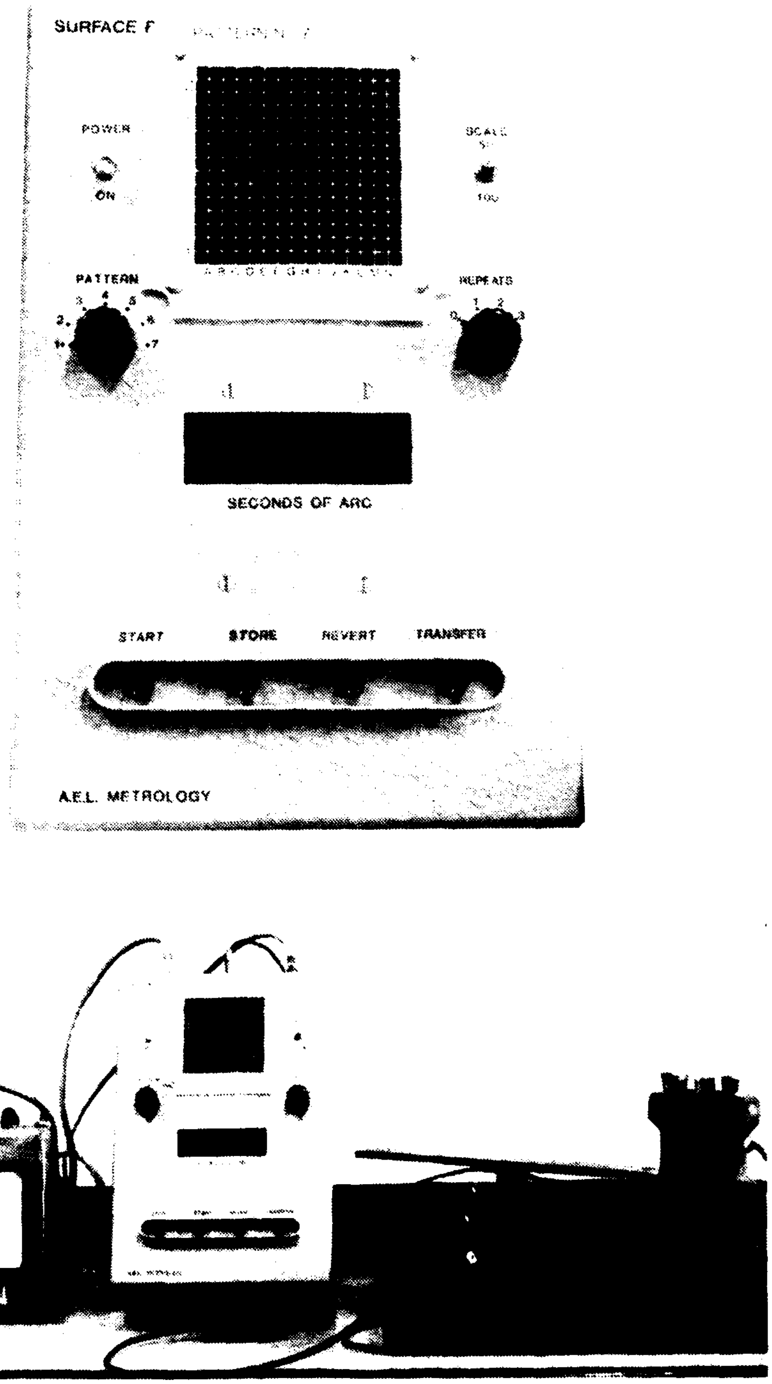


Figure 1. Data unit with Talyvel

## 2. THE DATA UNIT

Rotary switches on the unit front panel (figure 1), set grid Pattern No and number of repeats for each calibration. Two Light Emitting Diodes (LED), in a 15 by 15 array, display the measuring interval. Initially all intervals on the selected grid pattern are scanned rapidly to indicate the sequence of measurements and to confirm the selection. Pattern reselection generates a new scan on completion of the current scan. Insufficient space to store data is indicated by "F" displayed on the array and acquisition is inhibited.

An overlay, put on the array, blanks off unused LED and letters the x and y intervals. Each x-axis generator is scanned once plus the number of repeats, always in the same direction. This is followed by scans along the y-axis and diagonal axes generators. (see figures 5 to 11).

After one scan the command "Start" is accepted and selections are frozen. The first interval on the first x-axis generator, displayed on the array, shows where the Talyvel is to be placed. A Digital Panel Meter (DPM) on the Unit front panel reads gradient in increments of 0.2 s of arc. The reading is entered by pressing the button on the extended lead. The indicated interval is then adanced one step along the generator at the end of which it returns to the start for a repeat.

Repeats, compared with the average of previous entries, are rejected if the difference exceeds a given margin. The interval display flashes and a second entry, if accepted, advances the interval. If not, flashing continues but the command "Revert" allows reentry of all previous readings for that interval.

When all repeats for one generator are complete data are stored permanently, the values being displayed on the DPM and the relative interval indicated by a slow flash on the array. Interval increments are from left to right on the x-axis, from bottom to top on the y-axis and from bottom left to top right or top left to bottom right on the two diagonal axes.

"I" is displayed for 10 s when job is complete. Storing the identifier, NUMX and UMY (number of X and Y intervals), at the head and zero at the tail of the dataset enables transfer to the PC. Power can be removed or another dataset can be acquired.

Power can be removed before job completion with a partial identifier using the command "Enter" while holding "Store" down. The job is restarted at the point it had been stopped when power is restored. Using the command "Revert" with "Store" removes the partial identifier. Only data for completed generators are stored so the operator can use this facility to retrace a generator.

Data are transferred to a PC fitted with an Asynchronous Communications Interface (ACI) card. The Unit, linked to the PC via type D connectors at the rear, is switched on and, after one scan, "Transfer" is pressed. Transfers start automatically when the PC is switched on and the operator is then prompted for interval dimensions. The store, emptied only after transfer of the last dataset, ensures no loss of data if power fails.

Additional datasets can be acquired if adequate storage exists; the requirement for each pattern is as follows:

| Pattern No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Bytes | 49 | 75 | 97 | 245 | 337 | 345 | 449 |

Total available space is 2045 bytes.

## 2.1 Microprocessor

The Data Unit circuit (figure 2), uses a Z80 Central Processing Unit (CPU) (U10) and a 2716 Read Only Memory (EPROM) (U21) for a 1941 bite program. Interrupts are generated by monostable (U50), triggered when one of the command push buttons is pressed. The 8212 latch (U30), set according to the given command, is polled by an Input/Output Request (IORQ). Two monostables (figure 3(a)) prevent false interupts due to contact bounce on release by sensing only the negative going first edge. Four command push buttons include "Start", "Enter", "Revert" and "Transfer". A fifth button "Store", generates no interrupt and is used with one of the others to modify the code in the latch. A second 8212 latch (U46) is set by the selectors and interrogated during initialisation by IORQ.

The 2114 Random Access Memory (RAM), (U44) and (U45), offer 1 k bites for working area: temporary store, flags, pointers, counters, codes and the stack. The 2817a Electrically Erasible PROM (EEPROM) (U43) gives non-volatile storage for 2 k bites of data loaded bottom up. Additional data for partial sets are loaded top down. The 8255 Parallel Output Ports (U37) and the Dart Serial port (U34) pass digital data. The AD7574 Analogue to Digital Converter (ADC) (U47), samples gradient every 0.16 s outputting an 8-bit number onto the data bus. CPU clock divider (U59) gives 500 kHz to control conversion and Wait. A standard voltage reference, (U46) feeds the ADC. All peripherals except latches are memory mapped through the 74155 decoder (U25), on address lines 12 to 14.

A 4 MHz crystal oscillator drives the CPU and the A5-8116 baud rate generator is driven by a 5.0688 MHz crystal oscillator to give 300 baud.

Drivers, 1488 (U35) powered by ±15 V, and receivers, 1489 (U40) couple the DART to the RS232 transmission lines via PL2 to communicate with the PC. Two decoders, 74154 (U48) and (U49) interface between the parallel port A and the LED array. Three lamp decoders, 7447 (U52), (U54) and (U56) interface between parallel ports B and C and the DPM display lamps 7610 (U53), (U55) and (U57).

All components, except the LED array and the DPM are on one card wired to plugs PL1 and PL2 on the rear panel. Ribbon cable connectors on the card are for the displays. Regulators mounted under the card supply 1A at +5 V, 17 mA at -15 V and 5 mA at +15 V.

## 2.2 Patterns and LED array

Lower and upper 4 bits of port A, decoded into two sets of 1 in 16, give respective x and y coordinates for each LED. One LED glows when contents of L1POS are output via port A. An adjacent LED glows when contents of offset L2OFF are added. Both glow when outputs are rapidly alternated. To move the pair along a generator L1POS is incremented by L2OFF and the end is reached after NUMX or NUMY increments. The value in L1POS serves as a pointer for data storage.

To start a new generator all increments are removed and a sideways offset is added to L1POS thereafter incremented by L2OFF as before. The start of the second up or down diagonal generator requires an offset NUMX-NUMY added to L1POS on completion of the first diagonal.

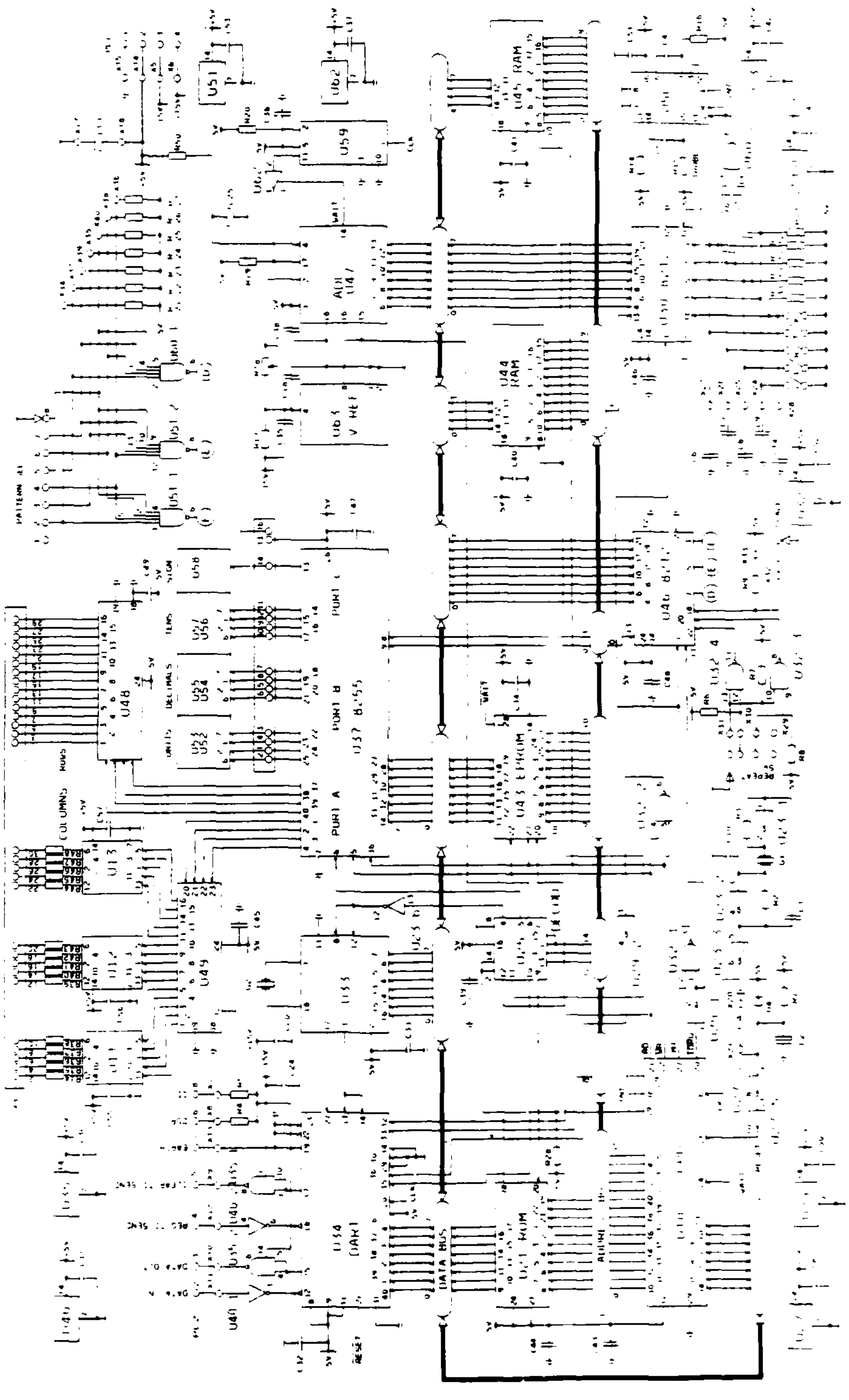

Figure 2. Data unit

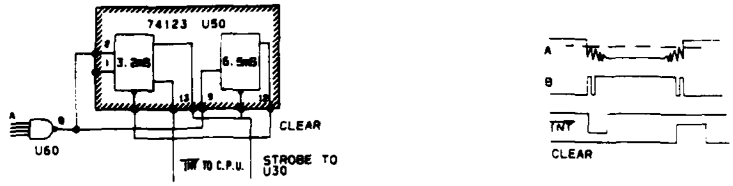


Figure 3(a). Dual monostable anti-bounce

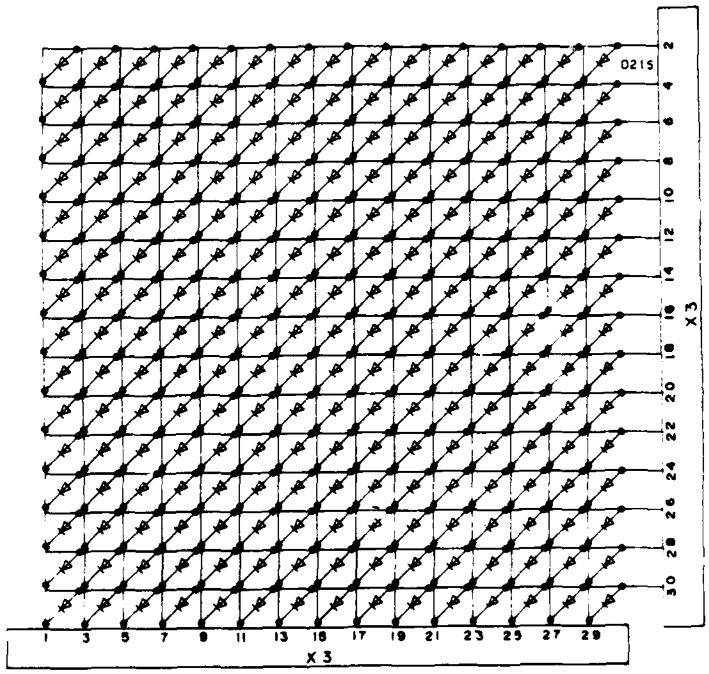


Figure 3(b). LED array

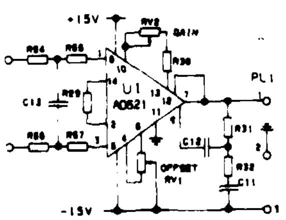


Figure 4. Talyvel instrument amplifier

Figures 5 to 11 are available patterns. Each LED is at a line intersection.

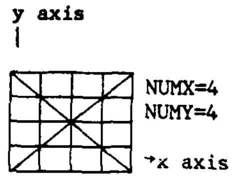


Figure 5. Pattern 1

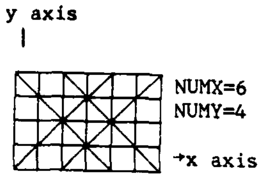


Figure 6. Pattern 2

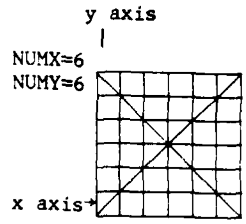


Figure 7. Pattern 3

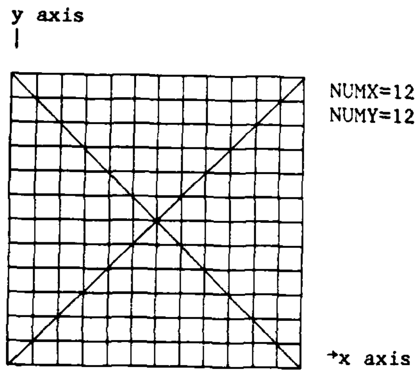


Figure 9. Pattern 5

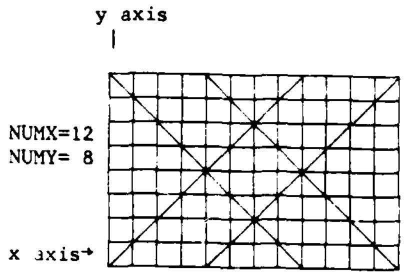


Figure 8. Pattern 4

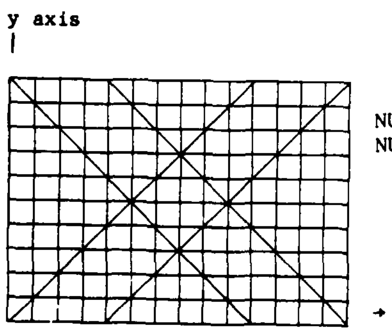


Figure 10. Pattern 6

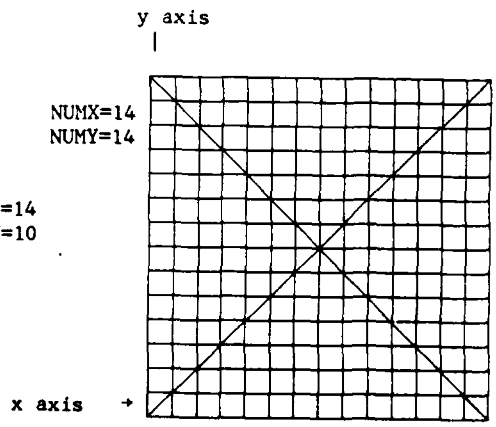


Figure 11. Pattern 7

## 2.3 The Talyvel

The response from the AC pendulum pickoff is amplified, demodulated and metered on a remote control unit. Modifications (figure 4) include amplifying and filtering the DC meter volts from a full scale range of between -0.25 V and +0.25 V to between 0 V and +5 V. RV1 is adjusted for zero DPM when the needle is centred and RV2 for equal DPM when the needle is at half scale. The filter cut off is 1 Hz and the pendulum natural frequency is 20 Hz.

Manual scale settings of ±50 or ±100 s of arc can be selected on both the control unit and the Data Unit. The 8-bit ADC gives 250 increments of 0.4 s of arc on the most sensitive Talyvel range. Program adds each sample from the ADC into half the contents of TALR. This gives a running average of sampled outputs and halves the scale to 250 increments of 0.2 s of arc. This, together with the filtering in the control unit, smoothes the signal and improves discrimination. The reduced full scale ±50 to ±25 s of arc is within the normal expectancy of gradient variations. The ±100 range, reduced to ±50 is available for worse cases.

## 2.4 Memory map and data allocation

U25 decodes address bits 12, 13 and 14 for Chip Select (CS) as follows:

TABLE 1. MEMORY MAP

| Address Range (low) | (high) | Decoder pin (low output) | Peripheral device | Part No |
|---|---|---|---|---|
| 0000H | 07FFH | 9 | ROM 2716 | U21 |
| 1000H | 1001H | 10 | DART Z80 | U34 |
| 2000H | 23FFH | 11 | RAM 2184 | U44 & U45 |
| 3000H | 37FFH | 12 | EEPROM 2817A | U43 |
| 4000H | | 7 | SPARE | |
| 5000H | 5000H | 6 | ADC AD7574 | U47 |
| 6000H | 6003H | 5 | PORTS 8255 | U37 |
| 7000H | 7000H | 4 | B.R.GEN.A58116 | U33 |

The first 22 locations in RAM are for Variables, Counters, Flags and Pointers. The next 30 locations are for temporary data storage, prior to loading into EEPROM. A variable block of locations from 23FFH down is for the stack.

Table 2 gives the state of the interrupt latch (U30) output onto the data bus when polled by IORQ and Address 0002H resulting from program instruction IN PORTI.

Table 3 gives the state of the selector latch (U46) output onto the data bus when interrogated by IORQ and Address 0001H resulting from program instruction IN PORTG.

TABLE 2. INTERRUPT CODES

| Interrupt | Latch Pin No (input low) | Data Word Binary Hex | Int Pulse -ve.going |
|---|---|---|---|
| START | 3 | 11111110 FE | 3.2 mS |
| ENTER | 5 | 11111101 FD | 3.2 mS |
| REVERT | 7 | 11111011 FB | 3.2 mS |
| TRANSFER | 9 | 11110111 F9 | 3.2 mS |
| ENTER & STORE | 5 & 16 | 11101101 ED | 3.2 mS |
| REVERT & STORE | 7 & 16 | 11101011 EB | 3.2 mS |

TABLE 3. SELECTOR CODES

| Pattern No. | Latch Pin No (inputs low) | | | Data word | Repts | Latch Pin No (inputs low) | | | Data word |
|---|---|---|---|---|---|---|---|---|---|
| 1 | - | - | - | xxxxx000 | 0 | -- | -- | -- | xx00xxxx |
| 2 | - | - | 3 | xxxxx001 | 1 | -- | -- | 16 | xx01xxxx |
| 3 | - | 5 | - | xxxxx010 | 2 | -- | 18 | -- | xx10xxxx |
| 4 | - | 5 | 3 | xxxxx011 | 3 | -- | 18 | 16 | xx11xxxx |
| 5 | 7 | - | - | xxxxx100 | Scale | | | | |
| 6 | 7 | - | 3 | xxxxx101 | 50 | -- | -- | -- | x0xxxxxx |
| 7 | 7 | 5 | - | xxxxx110 | 100 | 20 | -- | -- | x1xxxxxx |

## 3. DATA PROCESSING

Datasets transferred to the PC are sequentially filed PLATE?.DAT. The first line in any one set is NUMX, NUMY, dx and dy where dx and dy are real numbered interval spacings entered by the operator. Dimensional units for dx and dy, metric or imperial, are entered during the final printout.

The remaining lines of data are gradients for successive intervals measured in the specified sequence. Failure to follow this sequence gives an incorrect solution.

As illustrated in figures 5 to 11 generators form a rectangular grid and intersect at the points of calibration. Each point, numbered along the x axes from the bottom left to top right, is represented by one LED on the array. Patterns are chosen so that diagonals also intersect at numbered points. Departures computed by the IBM 370 are output in the same numbered sequence.

### 3.1 The mean plane

One definition of flatness considers the surface bounded by two parallel flat planes tilted for minimum separation. Separation is the figure for calibration. Another definition considers the surface as departures from a mean plane tilted about the horizontal to minimise the r.m.s. of departures. The sum of maximum departures above and below the mean plane is equivalent to the first definition. The solution gives a three dimensional profile of the surface so locating the high and low spots on the surface. Methods of computing are described(ref.1,2) and require a 700 k byte processor to solve.

The program SURFPLT.FORT runs on the IBM 370 and uses about 2 min CPU time for the largest pattern. This pattern, No 7, requires 448 gradient measurements and solves for 225 points of calibration. It involves the solution of a 260 x 261 matrix 8 bytes per element. Double precision is mecessary to avoid large error accumulations.

3.2 Calculation of departures

Data word $\alpha(j)$ is the measured gradient, in seconds of arc, between points i and i+1 at interval j on the x-axis. It is likely that the plate is tilted by more than 50 s of arc from the horizontal and the Talyvel must be biassed to bring the reading on scale. The bias $\theta(k)$ is assumed constant for generator k and is found in the matrix solution. $\theta$ has a slow drift and must be solved for each generator. Using laser beams $\theta(k)$ is fixed but unrelated to $\theta(k+1)$. Departures from the reference plane at points i and i+1, h(i) and h(i+1) respectively, are shown in figure 12.

$$h(i+1) = h(i) + dx.\alpha(j) + dx.\theta(k)$$

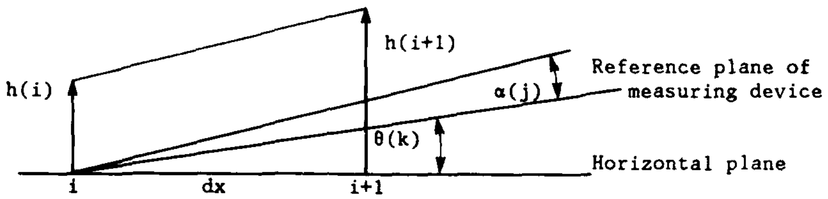


Figure 12. Measurement interval

Unknowns are h(i), h(i+1) and $\theta(k)$. Measured data are a(j) and the interval "dx" is entered manually. For y generators, "dy" is entered to replace "dx" and, for diagonal generators, "s", vector sum of "dx" and "dy", is computed to replace "dy". The number of unknowns (N) is the sum of the number of points of intersection and the number of generators. (M) equations exceed (N) so large measurement errors cause an ill conditioned problem. This is detected by program but, for small errors, the solution is the averaged values for the unknowns.

(M) and (N) are defined as follows

M = (NUMX+1).NUMY + (NUMY+1).NUMX + (NUMX+NUMY).2 (or 4 for non square patterns)

N = (NUMX+1).(NUMY+1) + (NUMX+1) + (NUMY+1) + 2 (or 4 for non square patterns)

The (M) equations written in matrix form become

$$A\, \underline{x} = \underline{b} \tag{1}$$

where A is an M.N matrix of known integer elements, $\underline{b}$ is a column vector of known data $\alpha(j)$ and $\underline{x}$ is a column vector of unknowns h(i) and $\theta(k)$.

Multiplying the transpose A' by A gives a square N.N matrix

$$A'.A\,\underline{x} = A'\,\underline{b} \tag{2}$$

Equation (1) is the "observational" and equation (2) the "normal". The normal equation solves for values of h(i) referred to the horizontal plane. To following conditions minimise the r.m.s. of departures with respect to a mean plane.

(a) sum of all h(i) equals zero

(b) sum of products of h(i) and x distance from centre equals zero

(c) sum of products of h(i) and y distance from centre equals zero

These conditions are expressed in matrix form as follows:

$$B\,\underline{x} = 0 \tag{3}$$

$$A'.A\,\underline{x} - B'.\lambda = A'\,\underline{b} \tag{4}$$

The additional term in equation (4) contains the Lagrange multipliers $\lambda$ which refer all h(i) to the mean plane. Equations (3) and (4) form a single square matrix (N+3).(N+3) which is solved for h(i), $\theta$(k) and $\lambda$. The solution forms the elements into a triangle giving one unknown in the bottom row. This is solved and entered into the next row up which again leaves one unknown. Working up the triangle solves all unknowns.

A proof of the conditions for a mean plane is given in reference 3.

## 4. FUTURE DEVELOPMENTS

The solution for Pattern No 7 requires 700 k bytes of active memory and the program uses 4 k bytes. A pattern 25 by 25 points would need over 2 M bytes of active memory and, to anticipate this, the program was designed to run on the IBM 370 with a G1 compiler. A graphics program, MOVIE, is resident on that machine and can be accessed.

Since the work was started a significant price reduction for a large memory PC has occurred. The program SURFPLT.FORT would need to be adapted to run on the PC and run time would be longer. However the advantage is a completely independent system unaffected be modifications to the IBM 370 or its compiler. The graphics program would then not be available but this in any case is rarely used.

Certain modifications to the Data Unit program are desirable. Six s to display data words during storage is excessive, prolonging acquisition time, and should be reduced to 3 s. The 5 s delay before interrupt enable should be reduced to 2 s. Although life of the EEPROM is quoted by the manufacturers as 100 000 write operations this may prove to be optimistic. The life could be extended if location 0 was used less frequently to identify data present. Some thought could be given to overcoming this problem.

Overlays, silk screened onto perspex, are liable to scratch marks. Glass would preserve a clearer view although more brittle. Some form of tilt is required also to improve the view of the display. A leather or vinyl carrying case should be provided if the Unit is to be portable.

Data unit hardware is permanent wired onto a base board. this should be replaced by a PCB if more equipments are ever made.

Talyvel damping appears more of a problem with the digital display. The eye can tolerate a slight dither of the meter needle but is much less tolerant to changing digital display. Increased digital smoothing may be desirable.

## 5. CONCLUSIONS

A time saving in processing has been achieved and greater savings in data acquisition could also be achieved. Mistakes in transferring readings are avoided and missed readings are quickly observed and corrected.

The system is adaptable to other methods of acquiring data. Since it uses standard RS232 serial communication it should operate with any compatible computer requiring only program development.

The equipment has proved easy to use and resistant to mains interference. However a longer period of trials is necessary to give final proof to this.

Report No. EE/MET/006/86

ADVANCED ENGINEERING LABORATORY
METROLOGY LABORATORY

EXAMINATION REPORT OF

Surface Plate Size 122 by 91 centimetres

9 X and 13 Y Generators, 117 Cal. Points, Margins: X = 7 Y = 5.5 cm

Departures from the Mean Plane Microns

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -5.21 | -4.17 | -2.33 | -1.85 | -1.60 | -1.40 | -0.78 | -1.60 | -0.99 | -0.53 |
| 11 | -1.35 | -2.32 | -3.31 | -3.74 | -2.01 | -1.02 | -0.11 | +0.47 | +0.65 | +1.27 |
| 21 | +0.65 | +0.29 | +0.32 | -0.73 | -1.22 | -2.58 | -0.72 | -0.13 | +0.68 | +0.96 |
| 31 | +1.97 | +1.55 | +2.31 | +1.21 | +0.89 | +0.82 | +0.23 | -0.86 | -1.81 | +0.62 |
| 41 | +1.15 | +1.77 | +2.27 | +2.73 | +2.55 | +3.02 | +2.49 | +1.96 | +1.48 | +0.73 |
| 51 | -0.59 | -1.87 | +0.89 | +2.36 | +2.81 | +3.09 | +2.75 | +2.53 | +2.58 | +2.45 |
| 61 | +1.74 | +1.24 | +0.65 | -0.73 | -1.84 | +1.56 | +2.54 | +2.91 | +2.92 | +2.88 |
| 71 | +2.38 | +2.65 | +1.81 | +1.53 | +0.85 | +0.05 | -1.15 | -2.61 | +0.90 | +1.81 |
| 81 | +1.89 | +2.01 | +1.89 | +1.76 | +1.98 | +0.69 | +0.76 | -0.27 | -1.10 | -2.24 |
| 91 | -3.84 | -0.19 | +0.70 | +0.60 | +0.61 | +0.60 | +0.70 | +0.62 | -0.44 | -0.73 |
| 101 | -1.50 | -2.08 | -3.98 | -4.76 | -0.95 | -0.98 | +0.28 | -0.58 | -0.46 | -0.60 |
| 111 | -0.91 | -1.63 | -2.25 | -2.68 | -3.25 | -4.97 | -6.46 | +0.00 | +0.00 | +0.00 |

Maximum +ve Departure = 3.0891
Maximum -ve Departure = -6.457

Temperature during examination 20 C.

| PREPARED | DATE | CHECKED | APPROVED | REFERENCE | |
|---|---|---|---|---|---|
| | 21/AUG/86 | | | EE/85/127 | SHEET 1 OF 1 |

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NATA SIGNATORY

Figure 13. Format for data presentation

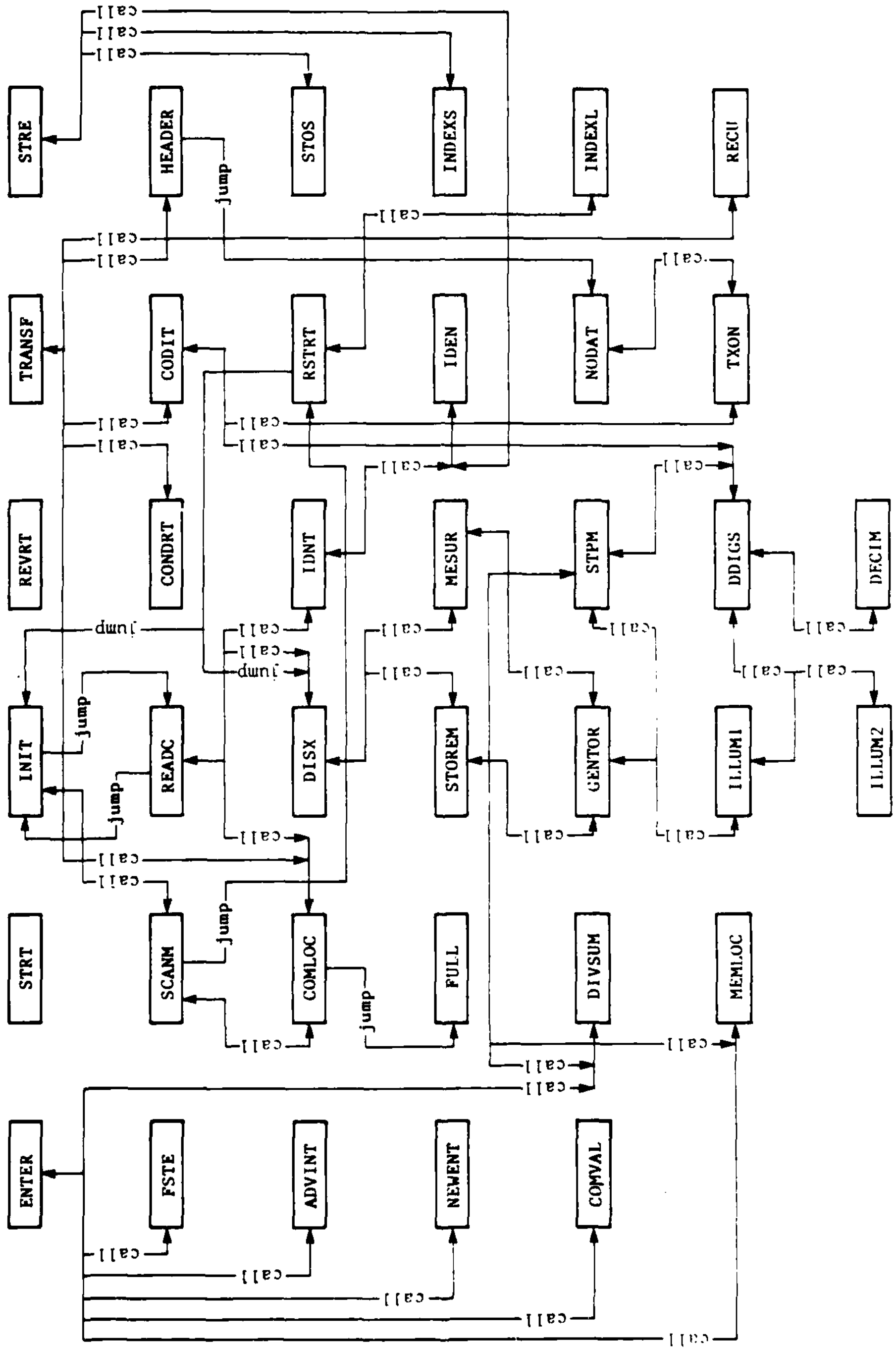


Figure 14. Data Unit module structure with jump and call links

## NOTATION

| | |
|---|---|
| A | Matrix of coefficients |
| A' | Transpose of matrix A |
| B | Matrix of mean plane conditions |
| B' | Transpose of matrix B |
| $\underline{b}$ | column vector of known data |
| $\underline{x}$ | column vector of unknown data |
| $\alpha(j)$ | gradient at interval (j) w.r.t. reference |
| dx | interval dimension along x-axis |
| dy | interval dimansion along y-axis |
| s | interval dimension along diagonal axis |
| $\theta(k)$ | reference angle for generator (k) |
| h(i) | departure w.r.t. reference at location (i) |
| $\lambda$ | Lagrange multiplier |
| NUMX | Number of intervals along x-axis |
| NUMY | Number of intervals along y or diagonal axes |
| M | Number of equations |
| N | Number of unknowns |

## REFERENCES


| No. | Author | Title |
|---|---|---|
| 1 | Prowse, D. | "The Calculation of the Mean Plane of a Surface Plate". Technical Note 73, Defence Standards Laboratory, November 1964 |
| 2 | Hayhurst, J. and Bell, J. | "Calculation of the Flatness of Surfaces by Electronic Computer". Technical Paper 24, N.S.L., C.S.I.R.O., 1968 |
| 3 | Macdonald, J. | "The Mean Plane of a Surface Plate". Report 166, Munitions Supply Lab, 1945 |

# APPENDIX I

## OPERATING PROCEDURE

### I.1 Data acquisition

Set the Data Unit adjacent to the surface plate and connect it to the Talyvel and power point. It should not be mounted on the plate as conducted heat affects accuracy. Mark out the plate in one of the seven patterns, lettering intervals and fitting the respective mask over the array. Record the intervals dx and dy. Set the x-axis of the array parallel to that of the plate. Select Pattern No. and No. of repeats. Set Scale on the Unit equal to that on the Talyvel Meter, usually ±50 s of arc. Switch on power and observe the display to confirm selection of pattern and repeats. To change a selection wait for one scan to be completed. Place Talyvel at given interval on plate and note reading then remove the Talyvel and replace it at the same interval and note second reading. Record the difference between readings and repeat for several intervals. Determine reasonable margin of error, then adjust the support screws to give a positive reading equal to the margin and ENTER.

To begin calibration press "Start" then place the Talyvel at the interval on the plate indicated by the array. Wait 15 s and, when the reading steadies, press "Enter". Move the Talyvel to the next interval indicated on the array, wait 3 s and, when steady, enter. If necessary note the readings down as they are entered.

After the last interval on the generator is entered, provided repeats are selected, the indicated interval will return to the start. On completion of repeats data are stored and each reading is displayed while the relavent interval flashes on the array for 5 s. Rejected repeats are indicated by rapid flashing and a further repeat <u>at that interval</u> may be entered. If still rejected press "Revert" and repeat all previous entries <u>at the one interval</u>. If this is accepted proceed to the next displayed interval.

When data for all x, y and diagonal generators are entered, "I" is displayed on the Unit for 5 s during which time the identifier is stored. Power must not be removed until the next rapid scan appears. Given adequate storage another set of data can be acquired in the same way. A full store is indicated by "F" on the array.

If the set cannot be completed in one session press "Enter" with "Store" held down then wait while "I" followed by "S" are displayed. This stores a partial indicator and allows power to be removed. When power is restored the display will indicate the start of the generator which was being measured before partial storage. This facility can be used to remove suspect data for a generator before completion. To remove the partial identifier press "Revert" with "Store" held down.

### I.2 Transfer from the Data Unit to the PC

Couple the Data Unit to the PC via rear panel 25 way type D sockets using the ribbon cable. Switch on power to the Unit and, when a scan is complete, press "Transfer". When the scan stops the Unit is read to transmit data. Insert "Surface Plate Cal B" disk into drive A of the PC leaving the door open. Switch on the PC and close the drive door. This causes the program "RECDAT.BAS" to run and to control data transmission. A number of messages and prompts (?) will appear. Reply to the prompts.

```
-- Message: -----DATA for SURFACE PLATENo. 1 now being entered.-----
-- Message: Number of X-Generators was __
-- Message: Number Of Y-Generators was __
--  Prompt: What was the Measuring Interval along X?  Enter dx with dec point
--  Prompt: What was the Measuring Interval along Y?  Enter dy with dec point
--  Prompt: dx =__._ dy = __._ Confirm (Y/N)?         Enter Y or N
         .
         .
-- Message: all data transferred
```

Enter intervals as real numbers in inch or millimeter units. Dimensions, Metric or Imperial, are decided during final print out (see Appendix III). If a second dataset exists the message "DATA for SURFACE PLATE No 2 now being entered" appears. When all data are transferred the Unit displays "E" and the VDU displays "All data Transferred"

For print out, if needed, type LOAD "READF.BAS" and then RUN. The dataset number is then requested. Values of dx or dy can be changed and a new dataset PLATEG.DAT created. PLATEG.DAT is renamed PLATE?.DATby entering SYSTEM (Disk Operating System) and using appropriate commands. Finally remove disk from drive A and switch off the PC.

I.3 Transfer between PC and IBM 370

Select a PC equipped with an IRMACARD, for transfer to the IBM 370, and a graphics printer. Insert disk "Surface Plate Cal A" into drive A and "Surface Plate Cal B" into drive B leaving both doors open. Switch on the PC then close both doors.

Prompt A> appears to indicate local command. Press both shift keys together to access the IBM 370, the PC now emulates a TSO terminal. Log on in the normal way and wait for the prompt READY. Return to local mode by pressing both shift keys. A period of 20 min is allowed before automatic logoff occurs so the following local transfer commands must be initiated within that period.

The program SURFPLT.FOR, on disk, is transferred to the IBM 370 and followed by one dataset. A series of prompts have to be answered for the program to run and a solution dataset obtained. The solution set is then transferred back to the PC.

I.3.1 Program transfer

Reply as shown to the following prompts:

| | |
|---|---|
| A> | Enter FT78T/S/V |
| What is the local filename? | Enter SURFPLT.FOR |
| What is the Data-set-name? | Enter SURFPLT.FORT |
| Operands? | Enter FORT |

Each line if the program SURFPLT.FOR is displayed on the VDU during transfer.

I.3.2 Dataset transfer

Reply as shown to the following prompts:

| | |
|---|---|
| A> | Enter FT78T/S/V |
| What is the local filename? | Enter B:PLATE?.DAT (Select appropriate ?) |
| What is the Data-set-name? | Enter SURFPLT.DATA |

| | |
|---|---|
| Operands? | Enter C/R |

Each line of data is displayed during transfer

I.3.3 Running the Program

The operator needs the command program "START" in his CLIST resident on the IBM 370. The program is run by commands from the PC in the TSO mode. Reply as shown to the following prompts

| | |
|---|---|
| A> | Press Both Shift Keys for TSO Mode |
| READY | Enter START |
| RECOMPILE? | Enter Y for 1st process N for remainder |
| PLOT ON? | Enter N |

Intermediate data are displayed during the process. Advance the display by pressing Enter when the screen is full. Finally departures from a mean plane will be displayed and filed in DEPART.DATA. A ill conditioned problem will display the matrix contents without presenting final departures.

| | |
|---|---|
| READY | Press Both Shift Keys for Local Mode |

I.3.4 Transfer solution back to the PC

Reply as shown to the following prompts:

| | |
|---|---|
| A> | Enter FT78T/R/O/V |
| What is the local filename? | Enter DEPARTS.DAT |
| What is the Data-set-name? | Enter DEPART.DATA |
| Operands? | Enter C/R |

Each line of data is displayed on the VDU during transfer. Previous data in file DEPARTS.DAT will be overwritten, so should be printed out before transfer of new data. To avoid loss a copy is made as follows:

| | |
|---|---|
| A> | Enter COPY DEPARTS.DAT DEPRTS?.DAT |

I.4 Report printout

Each set of results filed in DEPARTS.DAT is presented in report form on one A4 sheet. Reply as shown to the following prompts:

| | |
|---|---|
| A> | Enter PRINTO ensuring printer is on line. |
| for Metric Enter 1. for Imperial Enter 2? | Enter 1 or 2 |
| Report No? | Enter rrr/yy where yy are last digits of year |
| Reference No? | Enter yy/sss N.B. 6 keystrokes for both No's |
| Date? | Enter dd/mmm/yy Month in capitals 9 keystrokes |
| Give X & Y Dims in cm/in | Enter edge to edge dims of surface plate |

Figure 13 is a specimen printout. The PC is now in BASIC and, to proceed further, return to DOS by replying as follows:

| | |
|---|---|
| OK | Enter SYSTEM |
| A> | Press both shift |
| READY | |

Repeat I.3 and I.4 until data for all plates are printed, without terminating the 370 session. If, for any reason, operations in local mode are held up, press both shift keys and logoff. Logon a new session when ready. If a graphics plot is required proceed to I.5 instead of I.3. When finished logoff.

I.5 To obtain a graphics plot

MOVIE, on the IBM 370, gives a projected three dimensional view of the mean plane with magnified departures. A magnification factor of 10 000 is adequate for reasonable viewing. Log off at the PC and log on to a Tektronix terminal with hard copier. The screen display can be rotated into any convenient viewing angle and then printed out.

Each process creates two data files (SURFPLT.GEOM and SURFPLT.FUN) for MOVIE, overwriting previous files. Therefore, obtain graphics before processing the next dataset. The procedure at the Tektronix terminal is as follows:

Switch on Terminal and Hard Copier (the latter requires several minutes warm up)

```
                              Enter TSO (ring Ex 5357 for terminal on line.)
                              Enter uid SIZE(2000)   (uid is user ident)
                              Enter password and action screen commands.
-- READY                      Enter MOVIE

-- Select Next Part of Movie to Run (0-7)  Enter 1
-- Do you want to allocate the LEXIDATA    Enter N and wait

-- <READ GEOM FILE>           Enter uid/SURFPLT/GEO
-- <READ DISP FILE>           Enter C/R
-- <READ FUNC FILE>           Enter uid/SURFPLT/FUN
-- >>                         Enter WARP

-- Scale Factors for X,Y,Z Directions      Enter 0,0,10000

-- >>                         Enter ROTATE

-- <Axis,Angle> Angle in degrees           Enter X,-40

-- >>                         Enter ROTATE
-- <Axis,Angle>               Enter Y,40
-- >>                         Enter VIEW
```

A three dimensional plot of the surface appears on the screen with an exaggerated profile in z. A better view of the profile might be obtained using ROTATE about either X or Y axis. When the display is satisfactory press HARD COPY on the Tektronix keyboard. Figure 15 is a typical graphics plot.

An alternative contour plot can be obtained by entering CONTOUR instead of WARP. The number of labels and raster line separation is entered, typically 5,2. The range of departures is then entered.

To exit from MOVIE enter EXIT then 0 in response to "Select Next...". When READY appears logoff and return to the PC for the next process.

# APPENDIX II

## DATA UNIT SOFTWARE (SUP1V6.ASM)

The program, in assembler language, is constructed in modules interconnected by JUMP or CALL instructions. This structure is illustrated in Figure 14, and the function of each module is described below. For a complete listing of the program refer to SUP1V6.LST which contains ample comments and explanations.

The 1972 byte object program loaded into EPROM by UPM leaves 76 bytes spare. The source, SUP1V6.ASM, can be reedited on an ISIS equipment using CREDIT or EDIT. The latter is not recommended as memory is limited to handling smaller programs. It is compiled by ASM80 which generates LIST and OBJ datasets. The source program SUP1V6.ASM, together with EDIT, CREDIT, ASM80, UPM and the operating system are all on one 6 in disk labelled SURFPLATE.

Changes to pattern sizes are made by altering the look-up table PATTN defining numbers of intervals NUMX and NUMY for each interval.

The program starts automatically on switch on at INIT and runs READC, SCANM, COMLOC, DISX, MESUR, GENTOR, ILLUM1, ILLUM2, DDIGS, DECIM and SCALR. These, run repeatedly, scan the measurement sequence. START and ENTER are unmasked and interrupts are enabled after the first Talyvel display. Interrupt ENTER loads MARG with the displayed reading. Interrupt START sets flag START causing the scan to stop at the first interval for measurement. The above modules are run without interval increment and, additionally, run DDIGS and DECIM for digital display of gradient. Interrupt ENTER is unmasked and START masked.

Interrupt ENTER runs ENTER, MEMLOC, FSTE and ADVINT for first entries and MEMLOC, FSTE and ADVINT for first entries and MEMLOC, COMVAL, DIVSUM, NEWENT and ADVINT for repeated entries. ADVINT advances the interval and returns to program.

Interrupt REVERT, unmasked during COMVAL for error excess, sets a flag and forces the program to reenter all previous readings for the one interval. It remasks REVERT.

Interrupt TRANSFER is unmasked in SCANM if at least one previous dataset exists in EPROM. It freezes the display and runs TRANSF, CODIT, HEADER, NODAT, TXON, DDIGS, DECIM and RECU. If transfers data to the PC then empties the EPROM store displaying "E".

Interrupt STORE is unmasked after START. It runs STRE, STOS, INDEXS and IDEN to recover the starting point to continue a previously stopped measurement,

### 11.1 Module Functions

```
INIT:   Set SP=23FFH (Stack pointer to top of RAM). Reset RVRT=55H and START=55H (01010101 Flag code)
        Set BAUGN=55H (Baud Rate 300). Set DELY=55H (delay first entry 15 seconds, see 4.1)
        Set INDX1=3000H (base of EEPROM). Set INDX3=0000H (initial data store offset address in EEPROM).
        Reset FLASH=FFH (11111111 normal). Set ECNT=-6H (6 sec storing EEPROM).
        Set CONTR=80H (8255 to program ports A,B,and C for output). Set MARG=0AH (default 2 seconds).
        Scan EEPROM for uncleared datasets and redefine INDX1 as base for next dataset.            Call SCANM
--------------------------------END OF MODULE--------------------------------                     Jump to READE

SCANM:  Read INDX1 (location for Dataset Identifiers, NUMX & NUMY). If zero (no data) end module   Ret to INIT
                                                                If OFFH (partial data) reset start. Jump to RSTRT
        Compute Memory Space used by dataset and redefine INDX1                                      Call COMLOC
        Set MASK=09H (unmask START & TRANSFER). Repeat SCANM until zero identifier found.
--------------------------------END OF MODULE--------------------------------                      Ret to INIT

COMLOC: Compute Dataset Length: 2 NUMX NUMY+3 NUMY+NUMX, if NUMX=NUMY or 2 NUMX NUMY+5 NUMY+NUMX, if NUMY>NUMX
        Add 1 to dataset length for identifier and add total to INDX1 for next base address        Jump to RSTRT
        Test whether value in INDX1 is above 37FFH, top of EEPROM, if so display "F"                   Jump FULL
--------------------------------END OF MODULE--------------------------------   Ret to SCANM, READC or TRANSF

READC:  Read START flag. If set (00H) display first interval for measurement.                    Jump to READE
        Read Pattern selector. Fetch NUMX & NUMY from table PATTN and store.
        Read Repeats selector. Store RPT. Read Scale selector. Store SCALC.
        Test for memory space in EEPROM using current NUMX & NUMY                                    Call COMLOC
        Scan selected Pattern on LED array. Set Interrupt mode 1. Repeat READC                         Call DISX
--------------------------------END OF MODULE--------------------------------

DISX:   Set L1POS=00H and L2OFF=01H (start 1'st X-generator), Load No. of X intervals NUMX in Reg. C
        Load No. of additional X-generators NUMY in Reg. B. Sweep one generator                       Call MESUR
        Ax. If START set store data for one X-gentr. Add 10H to L1POS (next X-gentr). Decrement Reg.B  Call STOREM
        If Reg.B pos. Sweep next X-generator and repeat Ax                                             Call MESUR
        If Reg.B neg. start Y-generator

        Set L1POS=00H and L2OFF=01H (start 1'st Y-generator), Load No. of Y intervals NUMY in Reg. C
        Load No. of additional Y-generators NUMX in Reg. B. Sweep one generator                       Call MESUR
        Ay. If START set store data for one Y-gentr. Add 01H to L1POS (next Y-gentr). Decrement Reg.B  Call STOREM
        If Reg.B pos. Sweep next Y-generator and repeat Ay                                             Call MESUR
        If Reg.B neg. start Diagonal Up-generator

        Set L1POS=00H and L2OFF=01H (start 1'st DU-generator), Load No. of DU invervals NUMY in Reg. C
        Load NUMX-NUMY in Reg. B (Coordinates for next start). Sweep one generator                    Call MESUR
        Adu. Read START. If set store data for one DU-gentre. Add Reg.B. to L1POS (next DU-Gentre)    Call STOREM
        If Reg.B not zero Sweep next DU-generator. Zero Reg.B and repeat Adu & Bdu.                    Call MESUR
        If Reg.B zero start Diagonal Down-generator

        Set L1POS=NUMY'16 and L2OFF=F1 (start 1'st DD-generator, Load No. of DD intervals NUMY in Reg. C
        Load NUMX-NUMY in Reg. B (Coordinates for next start). Sweep one generator                    Call MESUR
        Add. If START set store data for one DD-gentre. Add Reg.B. to L1POS. (next DD-Gentre)         Call STOREM
        If Reg.B not zero Sweep next DD-generator. Zero Reg.B and repeat Add & Bdd.                    Call MESUR
        If Reg.B zero enable interrupts.
--------------------------------END OF MODULE--------------------------------                     Ret to READC

FULL:   Set MASK=08H (unmask TRANSFER). Fetch data words from table FULLR to display "F",
        Endless loop displays "F" until interrupted by TRANSF
--------------------------------END OF MODULE--------------------------------
```

```
MESUR:  Load repeat counter RPTC with repeats RPT. Load interval counter AXLIM from Reg.C.
        Sweep one generator. Decrement RPTC. If RPTC pos. repeat sweep.                      Call GENTOR
        If RPTC neg. restore L1POS to starting value.                                        Ret to DISX
--------------------------------END OF MODULE--------------------------------

STOREM: Set MASK=00H (mask all). Load interval counter AXLIM from Reg.C.
        Set FLASH=7EH (01111110 Code cycled lamps on for >88H)                               Call GENTOR
        Restore L1POS to starting value. Set MASK to 02H unmask ENTER.                       Ret to DISX
--------------------------------END OF MODULE--------------------------------

GENTOR: Read FLASH. If > 88H (coordinates D=FFH, E=00H), for "OFF". Rotate code              Call ILLUM1
                    If = FCH (11111100) store data in EEPROM.                                Call STPM
                    If > 88H (coordinates D=L1POS, E=L2OFF), for "ON". Rotate code           Call ILLUM1
        Read START. If reset add L2OFF to L1POS and decrement AXLIM.
        Read AXLIM. If pos. repeat GENTOR. If zero return to calling module.       Ret to MESUR or STOREM
--------------------------------END OF MODULE--------------------------------

ILLUM1: Set Reg.B=20H (loop counter for 0.133 secs).
        Read FLASH. If normal Read "Gradient", decimalise and display on D.P.M.
                    If Storing in EEPROM - continue
        A. Illuminate LED's Decrement Reg B. If not zero repeat A.                           Call ILLUM2
--------------------------------END OF MODULE--------------------------------      Ret to GENTOR

ILLUM2: Set Reg.B=60H (loop count). Read NUMX. If < 7 continue
                                               If > 8 double interval space on array
        A. L1POS in ACC. Complement for Array addressing. Illuminate lamp 1
        B. Add L2OFF. Complement for Array addressing. Illuminate lamp 2
        Decrement Reg.B If not zero repeat A. and B.
--------------------------------END OF MODULE--------------------------------      Ret to ILLUM1

DDIGS:  Convert "Gradient" to 2's Comp. Compare value with Overscale limit
                    If overscale Load ACC=AAH (display ccc).                                 Jump to POS36
                    If normal Fetch TALR and divide by 2. Add new value and store in TALR
        Decimalise modulus of value in ACC, sign in Rg.C.                                    Jump to DECIM
--------------------------------END OF MODULE--------------------------------

DECIM:  Decimalise modulus (max 24.9 in Reg. B&C). Double the value if SCALC set. Display digits   Jump to DECIM
        Decrement Interrupt enable delay DELY.
--------------------------------END OF MODULE--------------------------------  Ret to ILLUM1, STPM or CODIT

STPM:   Decrement Entry Count (ECNT), initial value 06H
                    If zero Advance Interval and Return to Calling Module                    Call ADVINT
                    If not zero Find RAM Address for stored Data.-continue                   Call MEMLOC
        Divide Data by RPT+1. Fetch INDX1 (EEPROM base Address). Add Incremented INDX3 (offset) to INDX1   Call DIVSUM
        Store Data in EEPROM. Decimalise and display Data byte being stored. Return to Calling Module      Call DDIGS
--------------------------------END OF MODULE--------------------------------      Ret to GENTOR

IDNT:   Set MASK=00H (mask all). Store NUMY in upper 4 bits & NUMX in lower 4 bits at EEPROM add. Indx1
        Display "I" for 4 s. Store Zero at EEPROM add. INDX1+INDX3+1                         Call IDEN
        Display "I" for 4 s.                                                                 Call IDEN
--------------------------------END OF MODULE--------------------------------      Ret to READC

IDEN:   Set Reg.B=80H, Reg.C=FFH (loop counters). Read Table IDENR. Count down Reg.C (inner loop)
        Count down Reg.B (outer loop)
--------------------------------END OF MODULE--------------------------------      Ret to IDNT
```

```
STRT:   "Interrupt Service". Set START flag. Set MASK to 02H (Unmask ENTER). Set SP to 23FFH (top of stack).
---------------------------------END OF MODULE---------------------------------          Jump to READE

ENTER:  "Interrupt Service". Find Temp Address for Data.                                  Call MEMLOC
        Read START. If reset load MARG with "gradient".                                   Ret to PROGRAM
                    If set continue
        Subtract RPT-RPTC. If zero (i.e. 1'st entry) Store.                               Call FSTE
                           If not zero (Repeat) (a) Average Previous Entries              Call DIVSUM
                                                (b) Compare with Average                  Call COMVAL
                                                (c) Add to Previous Entries               Call NEWENT
        Advance Interval. LoadDELY=14H (3 sec delay before next int. enable).             Call ADVINT
---------------------------------END OF MODULE---------------------------------          Ret to PROGRAM

MEMLOC: Compute Temp Address: Read L2OFF for Axis? Read L1POS for Interval? in REG.C.
        Add Reg.C. to EADD (Temp. base Address) in Regs.H,L
---------------------------------END OF MODULE---------------------------------          Ret to ENTER

DIVSUM: Load "Sum of Entries" into Regs.D,E. Load Divisor into Reg.C. Accumulate dividend in Reg.B.
---------------------------------END OF MODULE---------------------------------          Ret to ENTER or STPM

COMVAL: Read TALR (New Entry). Compare New Entry with Reg.B.
                    If error > MARG:  Set FLASH=88H (out of tolerance)                    Ret to ENTER
                                      Set MASK=06H (unmask REVERT & ENTER)
                    If error < MARG:  Set FLASH=FFH (normal)
---------------------------------END OF MODULE---------------------------------          Ret to ENTER

NEWENT: Read FLASH  If < 89H End Module                                                   Ret to ENTER
                    If > 88H Read TALR. (New Entry). Add to "Sum of Old Entries".
---------------------------------END OF MODULE---------------------------------          Ret to ENTER

ADVINT: Read FLASH  If < 89H End Module                                                   Ret to ENTER
                    If > 88H Read RVRT. If set (a) Decrement RPTC
                                               (b) Compare with RRCNT: If Pos End Module  Ret to ENTER
                                                                       If Zero Continue
                                      If reset Continue
        Add L2Off to L1POS (advance interval). Decrement AXLIM (interval count). Reset RVRT flag.
        Set ECNT=06H (EEPROM storing period)
---------------------------------END OF MODULE---------------------------------          Ret to ENTER

FSTE:   Read TALR (1'st Entry). Store at Temp Address.
------------ --------------------END OF MODULE---------------------------------          Ret to ENTER

REVRT:  "Interrupt Service". Load RRCNT with RPTC (readings entered). Load RPTC with RPT (repeats)
        Reset RVRT flag. Set FLASH=FFH (normal). Set Mask=02H (unmask ENTER)
---------------------------------END OF MODULE---------------------------------          Ret to PROGRAM

TRANS:  "Interrupt Service" Set SP=23FFH (top of stack). Set DART control.                Call CONDRT
        A. Wait for "U" from IBM PC.                                                      Call RECU
           Fetch Identifier (NUMX & NUMY for Dataset). Transmit Identifier.               Call HEADER
           Wait for "U" from IBM PC.                                                      Call RECU
           Set Regs D,E=(dataset length). If zero display "E". Find address for next DAtaset Identifier.   Call COMLOC
        B. Transmit data word to IBM PC. Increment H,L. Compare H,L & D,E. If D,E>H,L Repeat B              Call CODIT
        Repeat A & B.
---------------------------------END OF MODULE---------------------------------          End PROGRAM
```

```
RECU:    A. Read DARTC. If LSB=0 (no input) Repeat A.
                        If LSB=1 (input) Read DARTD. If Char;"U" Repeat A.
                                                     If Char="U" Return to Caller.
--------------------------------END OF MODULE--------------------------------      Ret to TRANSF

HEADER: Test Transmit Buffer. Send ZERO.                                              Call TXON
        Fetch Identifier. If zero Transmit 0,0 to the IBM PC. Clear EEPROM Memory.    Call NODAT
                          If not zero, Code NUMX & NUMY. Transmit as Decimal Digits plus Commas.   Call TXON
--------------------------------END OF MODULE--------------------------------      Ret to TRANSF

NODAT:  Test Transmit Buffer. Set DARTD=30H,=2CH,=30H,=2CH. (ASCII 0,0,)              Call TXON
        Set IDENT=00H (to clear EEPROM).
--------------------------------END OF MODULE--------------------------------      Ret to TRANSF

CODIT:  Read Data BYTE. Convert into 3 Decimal Digits.                                Call DECIM
        Test Transmit Buffer. Set DARTD="Sign",="10's",="1's",="0.1's",=2CH.          Call TXON
--------------------------------END OF MODULE--------------------------------      Ret to TRANSF

RSTRT:  Fetch NUMX, NUMY, RPTS, SCALC, INDX1 & INDX3 fro EEPROM Addresses 37FFH - 37FAH   Call INDXL
        Fetch L2OFF from EEPROM address 37F9H. Determine Axis and Jump Address.
        Fetch L1POS from EEPROM Address 37F8H.                    Jump to Appropriate part of DISX
--------------------------------END OF MODULE--------------------------------

INDEXL: Fetch Contents of EEPROM Address 37FDH - 37FAH and Load into INDXI, INDX2, INDX3 & INDX4
--------------------------------END OF MODULE--------------------------------      Ret to RSTRT

STRE:   "Interrupt Service" Store FFH at EEPROM Address defined in INDX1. Display "I"   Call IDEN
         Store in EEPROM: NUMY at 37FFH, NUMY at 37FEH, RPT & SCLC at 37FDH. Display "S"   Call STOS
         Store in EEPROM: INDX1 & INDX3 at 37FCH - 37F9H.                              Call INDEXS
         Store in EEPROM: L2OFF at 37F8H, L1POS at 37F7H. Display "S"                  Call STOS
--------------------------------END OF MODULE--------------------------------      Ret to PROGRAM

INDEXS:  Store in EEPROM: INDX1 at 37FDH. Display "S".                                Call STOS
         Store in EEPROM: INDX2 at 37FCH. Display "S".                                Call STOS
         Store in EEPROM: INDX3 at 37FBH. Display "S".                                Call STOS
         Store in EEPROM: INDX4 at 37FAH. Display "S".                                Call STOS
--------------------------------END OF MODULE--------------------------      Ret to STRE
```

Look up tables: DARTW, FULLR, IDENR, EMPTR and PATTN are locatedat the end of ROM. DARTW is a series of instructions to program the Z80 DART. FULLR, IDENR, EMPTR and STOSR are lists of point coordinates on the LED array to display "F", "I", "E" and "S" respectively. PATTN gives the values, NUMX and NUMY for the selected pattern. A polling routine at location 38H identifies the requesting interrupt and calls the appropriate service subruotine.

The module structure with Jump and Call links is shown in figure 14.

# APPENDIX III

## PC SOFTWARE

PC software is on two discs: "Surface Plate Cal A" and "Surface Plate Cal B". Disc "A" is for communication between the PC and the host. It is a system disc with the IRMACARD control program, activated, via AUTOEXEC.BAT, when the PC is switched on. Other programs on disc "A" are the Fortran source code SURFPLT.FOR and DEPRTS.BAS for print out.

Disc "B" is for communication between the PC and the Data Unit. It also holds the data for transmission to the host. Communication is controlled by RECDAT.BAS run via AUTOEXEC.BAT when the PC is switched on. Data on disc "B", transferred from the Unit, can be viewed via READF.BAS. A Basic complier and editor on disc "B" allows other programs to be written for data manipulation.

### III.1 RECDAT.BAS (disc B)

Communication between the PC and the Unit uses the OPEN "COM1" Basic instruction. Baud rates, parity checks etc. are set up in conformity with those in the Unit. Program sends "U" and waits for the idents NUMX and NUMY from which the number of x, y and diagonal generators is computed. Intervals dx and dy are entered manually after the prompt and program sends a second "U" to the PC. The Unit responds by sending the data stream which will be filed under PLATE?.DAT, data words being displayed during transfer.

After transfer the program sends "U" to request the next ident. If this is zero the message "All Data Transferred" appears and the program terminates. Otherwise the process repeats and the next set of data is filed in PLATE?+1.DAT.

### III.2 DEPRTS.BAS (disc A)

Processed data for any one plate are filed in DEPARTS.DAT (Appendix I.3.4) The batch program PRINTO.BAT runs the interactive Basic program DEPRTS.BAS which presents the data on A4 formatted paper on a graphics printer. The print out includes departures at all calibration points, maximum positive and negative departures from a mean plane and plate dimensions. The operator enters Reference and Report numbers, date and Metric or Imperial.

Figure 13 shows a typical print out of data. The program calculates space required for data which is well centered. The NATA logo and warning appear on the bottom of the page.

### III.3 READF.BAS (disc B)

This is run after entering BASIC and LOAD"READF". It prints all data transferred and enables changes to dx or dy to be made.

# APPENDIX IV

## PARTS LIST

### Integrated Circuits

| | | |
|---|---|---|
| U 01 | AD521 | INSTRUMENT AMPLIFIER |
| U 10 | Z80 | CPU |
| U 11 | 7404 | HEX-INVERTERS |
| U 12 | 7404 | " " |
| U 13 | 7404 | " " |
| U 21 | 2716 | EPROM |
| U 23 | 7404 | HEX-INVERTER |
| U 25 | 74155 | DECODER 3-8 |
| U 27 | 7414 | HEX-INVERTER |
| U 29 | 7404 | " " |
| U 30 | 8212 | LATCH |
| U 32 | 7400 | QUAD 2-INPUT NAND |
| U 33 | A5-8116 | BAUD RATE GENERATOR |
| U 34 | Z80 | DART |
| U 35 | 1488 | LINE DRIVERS |
| U 37 | 8255 | PARALLEL PORTS |
| U 40 | 1489 | LINE RECEIVERS |
| U 43 | 2817A | EEPROM |
| U 44 | 2114 | RAM |
| U 45 | 2114 | RAM |
| U 46 | 8212 | LATCH |
| U 47 | AD7574 | A to D CONVERTER |
| U 48 | 74154 | DECODER 4-16 |
| U 49 | 74154 | " |
| U 50 | 74123 | DUAL MONOSTABLE |
| U 51 | 7420 | DUAL 4-INPUT NAND |
| U 52 | 7447 | LAMP DECODER |
| U 53 | 7610 | LAMP DISPLAY |
| U 54 | 7447 | LAMP DECODER |
| U 55 | 7610 | LAMP DISPLAY |
| U 56 | 7447 | LAMP DECODER |
| U 57 | 7610 | LAMP DISPLAY |
| U 58 | | LED BAR |
| U 59 | 7493 | DIVIDER |
| U 60 | 7420 | DUAL 4-INPUT NAND |
| U 62 | 74125 | TRI-STATE INVERTER |
| U 63 | AD584 | VOLTAGE REFERENCE |

### Power Supply Regulators

| | |
|---|---|
| +5 Volt 1 Amp | AD 943 |
| ±15 Volt 150 mAmp | AD 940 |

### Resistors

| | |
|---|---|
| R 1 | 22K |
| R 2 | 330K |
| R 3 | 330K |
| R 4 | 1K |
| R 5 | 1K |
| R 6 | 10K |
| R 7 | 10K |
| R 8 | 10K |
| R 9 | 10K |
| R 10 | 10K |
| R 11 | 10K |
| R 12 | 10K |
| R 13 | 10K |
| R 14 | 10K |
| R 15 | 100K |
| R 16 | 100K |
| R 17 | 24K |
| R 18 | 2K |
| R 19 | 10K |
| R 20 | 10K |
| R 21 | 10K |
| R 22 | 10K |
| R 23 | 10K |
| R 24 | 10K |
| R 25 | 10K |
| R 26 | 10K |
| R 27 | 10K |
| R 28 | 10K |
| R 29 | 10K |
| R 30 | 110K |
| R 31 | 680 |
| R 32 | 330 |
| R 33 | 10K |
| R 34 | 100K |
| R 35 | 100K |
| R 36 | 100K |
| R 37 | 100K |
| R 38 | 100K |
| R 39 | 100K |
| R 40 | 100K |
| R 41 | 100K |
| R 42 | 100K |
| R 43 | 100K |
| R 44 | 100K |
| R 45 | 100K |
| R 46 | 100K |
| R 47 | 100K |
| R 48 | 100K |
| R 50 | 100 |
| R 54 | 100K |
| R 55 | 100K |
| R 56 | 100K |
| R 57 | 100K |

### Capacitors

| | |
|---|---|
| C 1 | 2200µ 16v TANT |
| C 2 | 100µ 6v3 TANT |
| C 3 | 10n |
| C 4 | 470n |
| C 5 | 100n |
| C 6 | 47n |
| C 7 | 47n |
| C 8 | 47n |
| C 9 | 47n |
| C 10 | 68p CERAMIC |
| C 11 | 1n |
| C 12 | 15n |
| C 13 | 1µ |
| C 14 | 47n |
| C 18 | 10n |
| C 20 | 100n |
| C 21 | 100n |
| C 24 | 100n |
| C 25 | 39µ10V TANT |
| C 31 – C 58 | 100n |

### Miscellaneous

| | |
|---|---|
| G 001 | 4.0 MHz HC18U XTAL |
| G 002 | 5.0688 MHz HC18U XTAL |
| D 004 | 1N4148 DIODE |
| D 005 – D 229 | ESBR3431 LED |
| RV 01 | 10K |
| RV 02 | 10K |

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16 SUMMARY OR ABSTRACT
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A method for acquiring and processing data for surface plate calibration is described. It controls acquisition procedure, minimises the work of analysis and presents the results as departures from a mean plane at a number of fixed points on the surface. Automatic entry and storage avoids copying errors when reading data.

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